EPSC Abstracts
Vol. 6, EPSC-DPS2011-899, 2011
EPSC-DPS Joint Meeting 2011


# Simulation of cloud formation in the atmosphere of Titan

I-Chun Tsai(1), Jen-Ping Chen(1), and Mao-Chang Liang(2)
1 Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan
2 Research Center for Environmental Change, Academia Sinica, Taipei, Taiwan

## Abstract

For understanding the cloud formation, a detailed microphysical model is modified to simulate nucleation, condensation and coagulation processes occurring in the atmosphere of Titan. The model is validated by laboratory results that synthesize particle formation in Titan-like environment. Model results show that the model could reproduce well the laboratory experiment results including time evolution of total pressures, number concentration and composition. Applying the model to a mimic Titan atmosphere, cloud layers could be formed at altitudes between 10-30 km depending on the strength of vertical transport. These particles could be produced by the $N_2$-$CH_4$ binary nucleation mechanism and be more effective than the falling tholin particle mechanism assumed in many current models.

## 1. Introduction

Several types of clouds are observed on Titan at different locations, including occasional cloud outbursts near south-pole (Schaller et al., 2006), southern mid-latitude cloud streaks (Griffith et al., 2005), and stratospheric ethane clouds at high northern latitude. Although the presence of clouds has been established, there is insufficient knowledge on their formation mechanisms, particle size distribution, and chemical composition. This study attempts to understand Titan cloud formation using a detailed microphysical model. The microphysical model was validated first against the laboratory result of Wang et al. (2010) and then applied to simulate Titan's cloud formation.

## 2. Multi-component microphysical model

The multi-component microphysical model we used for the study is modified from the model of Chen and Lamb (1994), which was designed for studying liquid- and ice-phase cloud microphysical processes on Earth (Chen et al., 1997; Chen and Lamb, 1999). These processes are modified for the $N_2$-$CH_4$ system in Titan's atmosphere.

## 3 Results

### 3.1 Microphysics simulation

A schematic diagram of the model setup is shown in Figure 1. Here we consider nucleation, condensation, and coagulation.

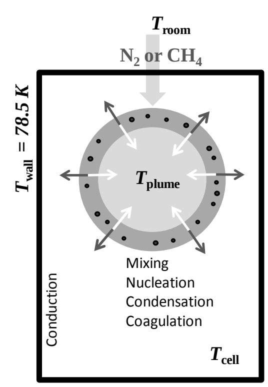


Figure 1: Schematic diagram of the model setup.

Wang et al. (2010) carried out experiments at conditions similar to the Titan atmosphere. The simulated pressure evolution fits well with the laboratory simulations for cases with ($N_2$ plume) and without ($CH_4$ plume) particle formation. The results are summarized in Figure 2.

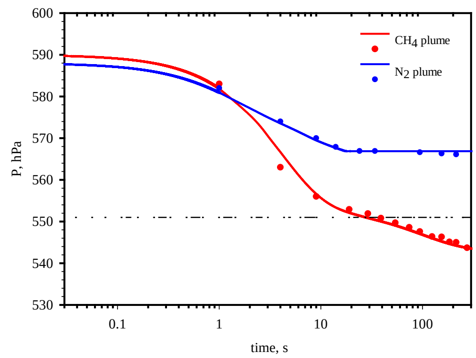


Figure 2: Pressure evolution of the model system.

Condensation growth of the particles after nucleation also involves both gases, as $N_2$ can dissolve into liquid $CH_4$. The nitrogen mole fraction in the simulated particles is about 30%, also rather close to the experimental value of 30±7 % that mentioned by Wang et al. (2010).

## 3.2 Application for Titan

We next apply the "laboratory calibrated" microphysics model for simulating $N_2$-$CH_4$ clouds in the troposphere of Titan. Vertical lifting can cause expansion cooling and thus an increase in saturation ratio which is critical to particle nucleation and condensation growth. Here, we run a parcel model to simulate cloud formation under different updraft speeds. The parcel is released from the 10-km height where $CH_4$ might be close to saturated (Atreys et al., 2006). The results and implication will be presented and discussed.

# References

[1] Atreya, S.K., Adams, E.Y., Niemann, H.B., Demick-Montelara, J.E., Owen, T.C., Fulchignoni, M., Ferri, F., Wilson, E.H., 2006. Titan's methane cycle. *Planet. Space Sci.*, **54**, 1177-1187.

[2] Barth, E.L., Toon, O.B., 2004: Properties of methane clouds on Titan: Results from microphysical modeling. *Geophys. Res. Lett.* **31**. L17S07.

[3] Barth, E.L. and Toon, O.B., 2006: Methane, ethane, and mixed clouds in Titan's atmosphere: Properties derived from microphysical modeling. *Icarus*, **182**, 230-250.

[4] Chen, J.-P., Lamb, D., 1994: Simulation of cloud microphysical and chemical processes using a multicomponent framework. Part I. Description of the microphysical model. *J. Atmos. Sci.* **51**: 2613-2630.

[5]Chen, J.-P., G. M. McFarquhar, A. J. Heymsfield, and V. Ramanathan, 1997: A modeling and observational study of the detailed microphysical structure of tropical cirrus anvils. *J. Geophys. Res.*, **102**, 6637-6653.

[6]Chen, J.-P., Lamb, D., 1999: Simulation of cloud microphysical and chemical processes using a multicomponent framework. Part II: Microphysical evolution of a wintertime orographic cloud. *J. Atmos. Sci.*, **56,** 2293-2312

[7]Griffith, C.A., Penteado, P., Baines, K., Drossart, P., Barnes, J., Bellucci, G., Bibring, J., Brown, R., Buratti, B., Capaccioni, F., Cerroni, P., Clark, R., Combes, M., Coradini, A., Cruikshank, D., Formisano, V., Jaumann, R., Langevin, Y., Matson, D., McCord, T., Mennella, V., Nelson, R., Nicholson, P., Sicardy, B., Sotin, C., Soderblom, L.A., Kursinski, R., 2005: The Evolution of Titan's mid-latitude clouds. *Science* **310**, 474–477.

[8] Schaller, E.L., Brown, M.E., Roe, H.G., Bouchez, A.H., 2006: A large cloud outburst at Titan's south pole. *Icarus* **182** (1), 224–229.

[9] Wang, C.C., Atreya, S.K., and Signorell, R., 2010: Evidence for layered methane clouds in Titan's troposphere, *Icarus*, 206, 787.